

Solutions Network Formulation Report

Reducing Light Pollution in U.S. Coastal Regions Using the High Sensitivity Cameras on the SAC-C and Aquarius/SAC-D Satellites

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1. Candidate Solution Constituents

- a. Title: Reducing Light Pollution in U.S. Coastal Regions Using the High Sensitivity Cameras on the SAC-C and Aquarius/SAC-D Satellites.
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Identified Partners: National Oceanic and Atmospheric Administration's National Geophysical Data Center, Boulder, Colorado; International Dark-Sky Association, Tucson, Arizona; National Environmental Satellite, Data, and Information Center's National Coastal Data Development Center; Colorado State University's Cooperative Institute for Research in the Atmosphere.
- c. Specific DST/DSS: A modified Garstang model in which mountain screening, Rayleigh scattering, Mie scattering by aerosols, atmospheric extinction, and elevation would be taken into account
- d. Alignment with National Application: Coastal Management, Public Health, Air Quality
- e. NASA Research Results – Table 1:

Missions	Sensors/Models	Data Product
SAC-C	High Sensitivity Camera	7-day, Monthly, and Yearly Global nighttime lights; Maps available through PO.DAAC (NASA Jet Propulsion Laboratory)
Aquarius/SAC-D		

- f. Benefit to Society: Maintenance of coastal ecological homeostasis, reduced human health risks from light pollution, preservation of water and air quality, and recovery of the night sky

2. Abstract

Light pollution has significant adverse biological effects on humans, animals, and plants and has resulted in the loss of our ability to view the stars and planets of the universe. Over half of the U.S. population resides in coastal regions where it is no longer possible to see the stars and planets in the night sky. Forty percent of the entire U.S. population is never exposed to conditions dark enough for their eyes to convert to night vision capabilities. In coastal regions, urban lights shine far out to sea where they are augmented by the output from fishing boat, cruise ship and oil platform floodlights. The proposed candidate solution suggests using HSCs (high sensitivity cameras) onboard the SAC-C and Aquarius/SAC-D satellites to quantitatively evaluate light pollution at high spatial resolution. New products modeled after pre-existing, radiance-calibrated, global nighttime lights products would be integrated into a modified Garstang model where elevation, mountain screening, Rayleigh scattering, Mie scattering by aerosols, and atmospheric extinction along light paths and curvature of the Earth would be taken into account. Because the spatial resolution of the HSCs on SAC-C and the future Aquarius/SAC-D missions is greater than that provided by the DMSP (Defense Meteorological Satellite Program) OLS (Operational Linescan System) or VIIRS (Visible/Infrared

Imager/Radiometer Suite), it may be possible to obtain more precise light intensity data for analytical DSSs and the subsequent reduction in coastal light pollution.

3. Detailed Description of Candidate Solution

a. Purpose/Scope

Detailed, high-resolution light pollution data is needed for coastal regions of the United States to estimate the amount of light pollution in these areas as it relates to global change and human, plant, and animal health. Forty percent of the U.S. population never sees conditions dark enough for their eyes to adjust for night vision capabilities (Cinzano et al., 2001). Because of ocular disturbances, light pollution in urban coastal areas may be responsible for disruption of human internal clocks, leading to altered sleep-wake cycles, impaired thinking, depression, and reduced nighttime hormone production. Lower levels of nighttime hormones can result in an increase in hormone-related cancers and in immune deficiencies (Gurd, 2006). The effects of light pollution are also far reaching in animals. Migration patterns are severely influenced in seabirds and in sea turtles, leading to the possible demise of the species (Weise et al., 2001; Salmon, 2003; Lindsay, 2003). In coastal waters, the change in nighttime lighting has led to a decrease in the vertical migration of zooplankton. This altered flux may lead to an increase in bacterial growth and a subsequent reduction in water quality in oceanic environments (Moore et al., 2000).

Light pollution has also reduced our ability to view the stars and planets of the universe (Duriscoe and Moore, 2002; Schwarz, 2003). Two thirds of the world's largest cities are in coastal regions. As seen by satellite, the brightest lights in the United States are in coastal regions where half of the total human population resides (Cinzano et al., 2001). These lights extend many miles out to sea where detrimental illumination effects are augmented by lights from fishing boats, cruise ships, and offshore oil platforms (Podolsky, 2003).

b. Identified Partner(s)

NOAA's NGDC (National Oceanic and Atmospheric Administration's National Geophysical Data Center, Boulder, Colorado. NOAA's NGDC is the home of the DMSP OLS archive and GTOPO30 elevation data that has been used in the Garstang light pollution model. NGDC scientists actively perform light pollution research and have developed radiance-calibrated, global nighttime light products for OLS data (Clark, 2003). Therefore, the experience of this group may be invaluable for developing new products for HSC sensor data.

IDA (International Dark-Sky Association), Tucson, Arizona. The IDA is a non-profit organization that focuses on the preservation and protection of the nighttime environment (IDA, 2007). Because the organizational goals are to identify sources of light pollution and then to mitigate their effects on air and water pollution, human health, wildlife, and ecosystems, the IDA may be a beneficial partner for future source identification, DST development, and light-pollution mitigation.

NOAA's NCDDC (National Coastal Data Development Center). The NCDDC has vast experience in coastal data management and data integration and may aid in the integration of HSC data with other coastal data parameters for DSS development.

Colorado State University's CIRA (Cooperative Institute for Research in the Atmosphere). Part of CIRA's mission is to improve interdisciplinary research in the atmospheric sciences and to assist the Nation through the application of research (CIRA, 2007). CIRA scientists have extensive experience with air quality, visibility, and remote sensing. Given CIRA's vast knowledge and extensive graduate student training program, it may be advantageous to partner with them for data integration and for new model development.

c. NASA Earth-science Research Results

Because the HSC has a much higher spatial resolution than the OLS or the VIIRS, the HSC can provide more detailed quantitative data on light pollution as it relates to human, plant, and animal health (Table 2). The HSC is on board the SAC-C satellite series that was launched in 2000 (eoPortal, 2007a). SAC-C is a joint effort between NASA, CONAE (the Argentine Commission on Space Activities), CNES (the French Space Agency), Instituto Nacional De Pasquisas Espaciais (the Brazilian Space Agency), the Danish Space Research Institute, and Agenzia Spaziale Italiana (the Italian Space Agency). Its primary scientific objective is to monitor the dynamic conditions of the terrestrial and marine biospheres (Colomb et al., 2003). Although SAC-C's lifespan was estimated to be 5 years, it is still operating normally as part of the first international Constellation of Earth Observation (the AM Constellation: Landsat-7, EO-1, Terra, and SAC-C). All satellites in the constellation pass over the same point within half an hour of each other so that data can be shared. SAC-C carries 11 different sensors including HSC. Such historical data can be used for rapid prototyping and quantification of light pollution intensity, perhaps on the Eastern Seaboard of the United States.

The HSC will also be onboard the Aquarius/SAC-D mission that is scheduled for launch in 2009 (eoPortal, 2007b). The Aquarius/SAC-D mission is a partnership between NASA and CONAE. The satellite will be in a sun-synchronous orbit with a 6 p.m. (ascending) equatorial crossing at an altitude of 657 km. This orbit will place the mission close to the day-night terminator with a global coverage of 7–9 days (Table 2).

The HSC sensors on SAC-C and the Aquarius/SAC-D mission are CCD imaging cameras with a spectral range of 450–850 nm, a spatial resolution of 200–300 m, and a swath of 700 km. HSC on SAC-C has a sensitivity of 0.1 saturation with a point source of 2 Kw, equivalent to 78 W/Dn. It can work in real time and has the capacity to store data (Colomb et al., 2003). The HSC on either mission can be used to study the light intensity in urban coastal areas, including fishing boats, oil platforms, cruise ships, electrical storms, and fires (Colomb et al., 2003; eoPortal, 2007a, b).

d. Proposed Configuration's Measurements and Models

Although the repeat time is slightly longer for SAC-C and Aquarius/SAC-D than for DMSP or for NPOESS (National Polar-orbiting Operational Environmental Satellite System) (7–9 days versus 1 day, respectively; Table 2), the HSC spatial resolution is greater than that of OLS or VIIRS, making it a valuable quantitative data collection resource. A comprehensive model could be developed in which light pollution data is integrated with air quality data and topographical information to obtain an interpretation of human, plant, and animal health in highly populated coastal regions of the United States. Air quality information is important because dust and smoke alter light intensity values.

Because NASA has no light pollution models, it will be necessary to draw on information and model systems that have been developed by the DMSP for the OLS sensor. At night, the OLS uses a photomultiplier tube attached to a 20-cm reflector telescope to intensify the visible bands. The spectral band ranges from 470 to 950 nm (Earth Observation Group, 2006a, b). The instantaneous field of view ranges from 3.0 km at nadir to 5.4 km at the edge of the scan (Elvidge et al., 1998). The OLS can detect low-level lights, fires, lava flows, lightning, and gas flares. If sufficient moonlight is present, the OLS can also detect snow cover, smoke, airborne dust, sea ice, and land surface features (Lee et al., 2006). Light pollution has been evaluated using modifications to the Garstang model (Garstang, 2000; Cinzano and Elvidge, 2004) in which elevation (from the GTOPO30 global digital elevation model by the U.S. Geological Survey's National Center for EROS), mountain screening, Rayleigh scattering, Mie scattering by aerosols, atmospheric extinction along light paths, and Earth curvature have been taken into account. A radiance-calibrated, global nighttime lights product has also been developed (Elvidge et al., 1999), and the contributions of each 30 x 30 arcsec² land area have been estimated using LPSKYMAP software (Cinzano and Elvidge, 2004). Although the lifespan

for the DMSP satellites is 4 years, coverage is expected until 2014 or 2016 when they will be replaced with the NPOESS and the European Meteorological Operational satellite program satellites (Bohlson et al., 2006).

As shown in Table 2, another sensor capable of detecting light at night is VIIRS on the NPOESS mission. The NPP (NPOESS Preparatory Project) will be launched in 2008 followed by NPOESS in 2010 (Lee et al., 2006). These missions will have global coverage in one day, data will be available in real-time, resolution will be moderate (0.742 X 0.742 km), and pre-launch and onboard calibration will be implemented. Both NPP and NPOESS will carry VIIRS sensors that have 22 channels, including a day/night band for nighttime viewing of city lights, lights from fishing boats, oil platforms, cruise ships, fires, and lightning, as well as nighttime clouds, dust, and smoke. Although VIIRS spatial resolution is significantly better than that of OLS, it is still moderate compared to that of the HSCs.

Table 2: Satellite sensor parameters for the identification of nighttime light pollution.

Satellite	Repeat Time at Night	Sensor	Swath Width	Spatial Resolution	References
DMSP	1 day	OLS	3000 km	5.3–2.8 km	Earth Observation Group, 2006a,b Lee et al., 2006
NPOESS	1 day	VIIRS	3000 km	0.74 km	Lee et al., 2006
SAC-C	7–9 days	HSC	700 km	0.2–0.3 km	Colomb et al., 2003
Aquarius/ SAC-D	7 days	HSC	700 km	0.2–0.3 km	Le Vine et al., 2006

4. Programmatic and Societal Benefits

Upward light data can be used to identify sources of light pollution so that measures can be made to reduce light emissions that affect the resident human, plant, and animal populations in coastal regions of the United States. Future NASA rapid prototyping efforts could be designed to obtain and test historical SAC-C HSC light pollution data over the Eastern Seaboard. In the future, sky glow could be quantified; the endangered parts of the sky could be identified and mitigation procedures could be implemented to preserve night views of the galaxy. In summary, NASA satellite-based light pollution data could be used to quantify the effect of altered night light intensities on public health, species survival, and our ability to see the universe from Earth.

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